THE EFFECT OF NUTRITION AND ENVIRONMENT ON BROILER TYPE CHICKENS

by

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INTRODUCTION

Economic pressures in the market place are continually requiring producers to raise broilers in a more efficient manner. Growers are replacing open or curtain sided facilities with environmentally improved houses where ambient temperature, relative humidity and light regimes can be more closely controlled. These improvements require large initial investment. However, birds in these facilities can be grown more efficiently by using increased stocking densities and less feed and fuel than in conventional houses. With these technological advances come many questions concerning how to best operate these facilities to meet the needs of the birds in an economical manner.

REVIEW OF LITERATURE

Light

A number of researchers have studied the effect of various lighting regimes on the productive performance and nutritional requirements of broiler type chickens. Light patterns for broilers have been altered from natural day light with artificial light at night, to continuous light at a single intensity, to intermittent (on-off) patterns as a means to improve over all bird performance.

Continuous. Several investigators have reported that bird performance under continuous, single intensity illumination was superior to that of birds given long periods of light and darkness (Moore, 1957; Shutze *et al.*, 1960; Beane *et al.*, 1962 and 1965; and Deaton *et al.*, 1970). Continuous light at a single intensity allowed the birds to establish a physical pattern for feeding and resting that was not influenced by outside light regimes and was more conducive to their physiological needs.

Deaton *et al.* (1970) compared broilers grown under continuous low intensity illumination (12.9 lux), with birds provided continuous light with varying intensities (12.9 to 204.5 lux) or 12 hours of light at 12.9 lux and 12 hours of darkness. They reported a superior body weight with a similar feed efficiency for birds reared under the continuous low intensity regime, and suggested that the improved performance was due in part to reduced broiler activity under this regime. This report is in agreement with both earlier and later investigations that have noted the trend for an increase in body weight from birds grown under continuous low intensity lighting when compared to those reared with natural lighting or other stimulatory lighting regimes (Skoglund, 1962; Skoglund and Palmer, 1962).

Deaton *et al.* (1976) also reported significantly better feed efficiency for birds given continuous low intensity light when compared with broilers receiving a varying intensity light treatment. They noted that the birds on high intensity light wasted more feed into the litter than those on low intensity, and that this was possibly related to the increase activity of the birds on the high intensity regime.

Intermittent. Baldwin and Kendeigh (1938) indicated that long periods of light (long day length) had an unfavorable influence on the body weight of undomesticated birds (ranging from song birds to ducks and geese). They concluded that long day length allowed the birds more time to expend energy. Lamoreux (1943) showed that chickens exposed to less than nine hours of light per day, in comparison to longer periods of light, had significantly greater gains. Furthermore, a number of investigators have shown that short light and dark periods (15 min to 2 hrs on:45 min to 4 hrs off) when compared to continuous light, increased the growth rate of chickens (Barrot and Pringle, 1950; Clegg and Sanford, 1951; Cherry and Barwich, 1962b; Skoglund *et al.*, 1966; Centa *et al.*, 1969; Gore *et al.*, 1969; Foshee *et al.*, 1970; McDaniel, 1972 and 1975; and Cain, 1973).

Work with laboratory rats by Cohn and Joseph (1960) and Leveille and Henson (1965) suggested that the alteration of the feeding behavior from "nibbling" to "meal eating", as would be done with intermittent lighting, allowed the animals to more efficiently use the feed ingested. The same trend of increased efficiency was noticed in humans by Romsos and Leveille (1977), and they concluded the improvement was due in part to a period of reduced activity after the meal.

A number of researchers have reported a general improvement in broiler body weight when low intensity, intermittent light regimes (5 to 54 lux) were compared with low intensity continuous regimes (Buckland *et al.*, 1971, 1973 and 1976; Hooppaw and Goodman, 1972 and 1976; Dorminey and Nakaue, 1977; McDaniel *et al.*, 1977; Cherry *et al.*, 1978 and 1980; Goodman, 1978; and Beane *et al.*, 1979). Furthermore, Quarles and Kling (1974) indicated improvements in feed efficiency when broilers were provided intermittent versus continuous illumination.

Male broilers grown under intermittent light (15 min on:90 min off) at a constant intensity (18.8 lux) were significantly heavier at four weeks than males grown under continuous light with decreasing intensity (18.8 lux to 1.6 lux) (McDaniel *et al.*, 1977). Similar body weights were found among females at this age. At seven weeks, both sexes grown under the intermittent regime were significantly heavier. These researchers suggested that this improved performance was due in part to the reduced requirements by the bird for energy during the dark cycle. This observation is in agreement with work reported by

Ota (1967) who indicated that birds produce 25% less heat in darkness than during light periods. In general, birds under reduced intensity lighting tend to be more docile than those on high intensity illumination. Therefore, it can perhaps be stated that energy expenditure is less on low intensity lighting regardless of the lighting pattern (continuous or intermittent).

Barrott and Pringle (1950), when evaluating different intermittent light patterns for chickens, reported that while the total hours of feeding time were important for maximum performance, the spacing of the feeding periods with the rest periods also had a significant influence on growth. They found that each feeding period had to be long enough to insure that the bird was fully fed, and that the rest period be of proper length so the crop could empty, allowing the bird to eat at the next feeding period. Their results indicated that a chicken will eat a maximum amount in one hour, and that in three to four hours it will feed again. They observed that a combination of one hour of feeding and two hours of rest did not allow sufficient resting time to encourage full feeding by the chickens at the next feeding period. However, Dorminey and Nakaue (1977) observed better performance with intermittent lighting patterns when the dark periods did not exceed two hours, and the light or feeding periods were of similar length.

Perhaps some of the inconsistencies in performance under intermittent versus continuous light can be explained by improper timing of the light and dark periods, which may not allow time for food passage from the digestive system. Investigators have reported that the food transit time through the gut of the chicken is about three to four hours (Hillerman *et al.*, 1953; Bell and Freeman, 1971; and Cherry and Siegel, 1978). However, large variations in this time have been observed. Tuckey *et al.* (1958) noted that transit time could be influenced by age, breed, sex, type of diet, and testing procedure.

Feeding space. Several researchers have postulated that broilers under intermittent light require more feeding space than birds under continuous illumination, because of the reduced feeding time induced by the periods of darkness (Hooppaw and Goodman, 1976; Cherry *et al.*, 1980; and Nakaue, 1981). Weaver *et al.* (1982) reported a light regime x feeding space interaction for body weight and feed efficiency when continuous and intermittent (1 hr on:2 hrs off) lighting patterns, and feeding space levels of 1.47 and 2.94 cm/bird were provided. They found in two experiments that body weight was actually depressed under intermittent light at the lower feeding space level. However, when provided increased feeding space, body weight improved under intermittent light in comparison to a continuous regime. These researchers also reported that broilers under intermittent light had a better feed utilization rate than continuously lighted birds when provided with more feeding space, and the reverse being observed with less feeding space.

Proudfoot (1973) reported a similar light regime x feeding space interaction when continuous and intermittent (1 hr on:3 hrs off) photoperiods and a series of feeding space levels (from .74 to 2.94

cm/bird) were used. Unfortunately, he did not report the direction of these relationships. Malone *et al.* (1980b) conducted a group of experiments using feeding space levels of 1.8, 2.3 and 2.7 cm/bird and continuous and intermittent (15 mins on:45 mins off, and 2 hrs on:4 hrs off) lighting patterns. Other than a light x feeder space interaction for feed efficiency at 27 days of age in one experiment, they found that these various feeding space levels had no effect on body weight or feed efficiency under these light regimes. These feeder space levels were intermediate to those reported by Weaver *et al.* (1982) and possibly were too similar to induce a significant response.

In another experiment, Malone (1980b) suggested that broilers failed to respond to intermittent light when provided 1.8 cm of feeding space because of insufficient feeding time. They observed that the number of birds feeding at the beginning and end of the light periods was similar, indicating a possible restriction of feeding space. Thus, the apparent inconsistencies in the performance of broilers, under both experimental and commercial conditions, when using continuous and intermittent photoperiods may be explained in part by the different amounts of feeding space provided.

Diet. Cherry *et al.* (1978) and Malone *et al.* (1980a) demonstrated that diets containing high nutrient densities [3465 kcal metabolizable energy (ME)/kg and 24.4% protein and 3307 kcal ME/kg and 25.1% protein, respectively] produced heavier broilers with continuous low intensity lighting than with intermittent lighting programs. Furthermore, Cherry *et al.* (1978) reported a light x diet interaction, indicating that body weight increased more rapidly under continuous than under intermittent light with increases in dietary energy. Malone *et al.* indicated a similar but nonsignificant light x diet interaction. They postulated that the lower gains observed under intermittent lighting may have been influenced by insufficient feeding time. These researchers also noted that pellet quality was poorer with the high energy diets, which possibly increased the feeding time on the higher density feeds.

These findings are inconsistent with those of Buckland *et al.* (1971) who suggested that chicks under intermittent (1 hr on:3 hrs off) when compared with those on continuous light needed more feeding time on lower as opposed to higher density diets (17.5% and 22.5% protein, respectively). Additionally, Conard and Kuenzel (1978) stressed the importance of feeding higher energy diets (3458 kcal ME/kg, 23% protein) to broilers under intermittent light regimes to compensate for the reduced feeding time. More recently, Brown and McCartney (1982) concluded that broilers on short interval feeding programs (15 min on:2 to 4 hrs off) should be fed a moderately dense diet (3400 Kcal ME/kg, and 23% protein) to obtain the best gains and feed efficiency at market age.

Leg Abnormalities. The percentage of broilers demonstrating weak or twisted legs have increased under commercial conditions as body weights have increased, and when birds are placed in facilities that provide reduced light intensity. These abnormalities are recognized as a syndrome that can be influenced by genetics, nutrition, pathogenic organisms and/or environmental conditions.

Birds grown under intermittent light have shown a significantly lower incidence of leg abnormalities when compared with similar birds on continuous photoperiods (Buckland *et al.*, 1973 and 1976). These researchers found that the abnormalities were reduced and body weights and feed efficiencies improved under intermittent regimes of one hour of light and one to three hours of darkness. They also reported that males have twice as many leg disorders as females. Furthermore, they postulated that some of this increase could be attributed to males being heavier than females when marketed.

In general, researchers have observed that birds grown under continuous low illumination are more docile, thus receiving less exercise than chickens on other stimulatory lighting patterns. With floor space allowance per bird continuing to decrease in commercial facilities, bird movement is further reduced which may increase leg abnormalities under low light intensity environments. However, it would appear that leg abnormalities can be altered with various light regimes.

Abdominal fat. Consumers have become more fat conscious in recent years, and find the obvious fat deposits in the abdomen of dressed poultry objectionable. Various lighting regimes have been found to play a role in fat deposition in chickens. Malone *et al.* (1977) and Cave (1980) observed significantly less leaf fat in both male and female broilers under intermittent when compared with continuous light.

Conard and Kuenzel (1978) found comparable body fat levels from birds grown with five daily feeding periods and those fed *ad libitum*.

Beane *et al.* (1979) reported increased abdominal fat under intermittent when compared with continuous light for female but not male broilers. Buckland *et al.* (1971) also reported significantly greater amounts of abdominal fat from birds under light regimes similar to those used by Beane *et al.* (1979). Malone *et al.* (1980b) found males reared on intermittent light (15 min on:45 min off) to have significantly more abdominal fat than continuously lighted males, while the females were not significantly altered. In the same report, when broilers were grown under longer intermittent periods (2 hrs on:4 hrs off) both sexes were found to have abdominal fat levels similar to the continuously lighted controls. Research by Deaton *et al.* (1978) was in agreement with these reports; they found no differences in percentage ether extract among birds provided with continuous and intermittent light treatments.

Cohn and Joseph (1960) found that when rats were converted from "nibblers" to "meal eaters", more efficient body weight gains resulted. Also, they found that the "meal eating" rats had a significantly higher percentage of body fat. The more efficient utilization of ingested nutrients was related to the reduced activity after the meal. Romsos and Leveille (1977) demonstrated with humans that greater weight gains occurred when meals were followed by periods of reduced activity. More recent investigations have shown that periodic versus *ad libitum* eating not only increases fat deposition, but also fatty acid synthesis and lipogenic enzyme activity (Simon and Brisson, 1972; Leveille *et al.*, 1975 and Nir *et al.*, 1979).

Several researchers have reported that body composition of chickens can be altered by changing the calorie to protein ratio (Donaldson *et al.*, 1957; Summers *et al.*, 1965). Spring and Wilkinson (1957) found that eight week old birds had increased body weight (from 1118 to 1171 gm) and increased body fat (from 6.0 to 9.1%) but decreased body protein (from 22.1 to 21.2%) and water (from 69.6 to 67.8%) levels when dietary energy was increased from 2640 to 3300 kcal ME/kg. Furthermore, they reported that body composition was reversed and gain was uneffected when dietary protein was increased from 22 to 28%.

Rand *et al.* (1957) working with chicks reported that dietary energy was related to percentage carcass fat when protein consumption was constant. They found that when dietary fat increased, the percentage of body fat originating from the ingested fat also increased. This trend was curtailed with high levels of protein which caused a reduction in the portion of carcass fat derived from dietary fat.

Ambient Temperature and Relative Humidity

Temperature and relative humidity are factors that can be controlled within practical limits in environmental poultry houses today. Because of the cost associated with controlling each of these parameters, producers are interested in the effect of these variables individually and in combination on broiler performance.

Temperature. In order to maintain body temperature, homeotherms are required to consume more feed under low versus high ambient temperature conditions (Kleiber and Dougherty, 1933; Ota and Garver, 1954; Cerniglia *et al.*, 1976). When chickens were grown (after the brooding period) under temperatures ranging from 13-35° C, the birds in the cooler environment were heavier but were less efficient utilizers of feed than those provided the warmer conditions (Howes *et al.*, 1962). Prince *et al.* (1960) using a temperature range from 7 to 24° C found a similar trend of better feed efficiencies with high temperatures. However, they reported that birds under the high temperatures had slightly better gains. The apparent contradiction in broiler gains in these two studies may have been due to the lower upper range of warmer temperatures used by Prince *et al.*

Barrott and Pringle (1947, 1949 and 1950) conducted a series of experiments to determine the most desirable temperatures for maximizing body weight and feed efficiency of chickens. They reported that chicks had the best growth and efficiency when brooded at a temperature of 35° C starting on the first day and gradually reduced to 31° C by the ninth day. They stated temperature should be dropped to 27° C by the 18th day and 19° C by the 32nd day. This schedule is in agreement with the finding of several investigators who have reported that body weight gains were significantly improved when broilers were grown (4 wks to market) under temperatures below 21° C when compared to those grown with higher temperatures (Prince *et al.*, 1960; Adams *et al.*, 1962; Huston, 1965; Mickelberry *et al.*, 1966). Deaton *et al.* (1968) attributed the slightly lower gains under the highest temperature regimes to reductions in feed consumption, and thus, decreases in total nutrient intake. Cerniglia *et al.* (1976) further documented this finding by reporting a 22% decrease in feed consumption for every 5° C increase in temperature above 24° C, with the major reduction occurring after four weeks of age. They observed that both males and females responded similarly under the various temperature regimes. Deaton and Reece (1970) observed that birds were six to eight percent heavier when grown (from 4 to 8 wks) under temperature regimes of 18 and 21° C when compared with broilers provided a 24° C temperature treatment. Furthermore, feed efficiency was improved by two to nine percent with a 21° C regime when compared with the lower temperature treatment. They concluded from these trials that a temperature of 21° C should be recommended during the growing phase when attempting to maximize both growth and feed efficiency.

A study by Carr *et al.* (1976) indicated that initial brooding temperatures can be reduced without adversely effecting weight gain or feed efficiency of broiler chickens. These researchers reported that broiler weight and feed efficiency at market age were not influenced by brooding temperature of 25° C during the first week when compared with a more usual brooding temperature of 29° C. This is in agreement with Reece and Deaton (1968), who reported that reduced heat level during brooding produced birds weighing 13% less than conventionally brooded birds at three weeks of age. However, no differences were found in body weight or feed efficiency at market age.

Relative Humidity. Relative humidity (RH) when maintained in a range between 57 and 71% had little effect on bird body weight or feed efficiency during the first two weeks of life (Barrot and Pringle, 1947; Siegel and Coles, 1958). Broilers at 10 weeks of age were observed to have a 44% improvement in body weight when grown at a temperature of 27° C in comparison to 35° C when RH was maintained at 93% (Milligan and Winn, 1964). However, when relative humidity was lowered to 40%, the improvement in weight gain under the low versus the high temperature was only 26%. Winn and Godfrey (1967) found that neither high nor low RH (93 or 30%) influenced body weight or feed efficiency of broilers until ambient temperature exceeded 27° C. At this point the effect of temperature and the higher level of RH became additive, causing increased mortality. When temperature was increased from 27° C to 35° C, rate of gain decreased 13% at the low RH (30%), and 31% at the higher level of humidity (93%). Furthermore, feed efficiency was poorer at 35° C and 93% RH than at 35° C and 30% RH or 27° C and 93 or 30% RH. These reports are in agreement with the results of Wilson *et al.* (1957), who observed weight losses in laying hens when housed at temperatures of 34 to 36° C. They suggested that high ambient temperature adversely affected chickens, especially when in combination with high relative humidity.

Deaton and Reece (1970) demonstrated that broiler body weight and feed efficiency were significantly improved as ambient temperature decreased from 35 to 32° C when dew point temperature was maintained at a constant 25° C. An additional seven percent improvement in body weight gain was recorded when temperature was further reduced to 29° C. No additional improvements in gain or feed efficiency were noted as temperature was further reduced to 27° C. However, at this point RH was at 87% (dew point 25° C).

The influence of temperature and relative humidity on feathering was also studied by Winn and Godfrey (1967). They reported that a low temperature of 8° C forced birds to huddle together, causing more of their feathers to be broken. Birds in low temperature, low relative humidity pens (8° C and 40% RH) had the poorest feathering score, while birds given high levels of humidity under the low temperature had improved feathering.

OBJECTIVES

Commercial broiler houses today are designed to control as many environmental factors (i.e., light, ambient temperature, relative humidity, etc.) as is economically feasible. Most of these buildings are well insulated and mechanically ventilated. Some are totally enclosed and provide an opportunity to practice various stimulatory lighting regimes. With the use of supplemental heat during colder months and evaporative cooling during warmer months, temperature and relative humidity can be maintained at near optimum levels. The objectives of these experiments were:

1. To study the performance of broilers provided two lighting regimes.
2. To measure the influence of two amino acid and two feeding space levels on broiler body weight and feed efficiency.
3. To determine the influence of two ambient temperature and two relative humidity regimes on broiler body weight and feed efficiency.
4. To evaluate the effects of these treatments on leg abnormalities and percentage abdominal fat.

MATERIALS AND METHODS

Two experiments were conducted in 32 floor pens each of which measured 1.52 x 3.66 m. All pens were designed to be void of outside light and to control ambient temperature and relative humidity. Each experiment contained 2400 male chicks of a commercial broiler cross. The chicks were placed on pine shavings spread to a depth of 7 cm. Seventy-five chicks were placed in each pen, providing a stocking density of .074 m^2. All chicks were vaccinated for Marek's disease, and were not debeaked.

Experiment I (Exp I). In the first experiment, two lighting regimes, two dietary amino acid levels and two feeding space levels were arranged in a factorial manner. Each treatment was replicated four time. All birds received 24 hours of light at an intensity of 65 lux until seven days of age. The birds in one-half the pens were then placed on an intermittent lighting (IL) regime, with one hour of light and two hours of darkness on a 24 hour basis. The remainder of the birds were kept on continuous illumination (CL). Light intensity in all pens was gradually reduced to 3 lux at 28 days and then remained constant until the end of the experiment.

Two commercial type broiler diets were fed providing a high and a low plane of nutrition (Tables 1 and 2). The low diets were calculated to contain 100% of the NRC requirements for lysine and total sulfur amino acids, and the high diets were calculated to contain 106 and 114% of these ingredients, respectively. The birds were provided

Table 1. High amino acid diets

	Starter	Grower	Finisher	With-drawal
Ingredients (kg)				
Corn	608.93	625.61	685.32	725.47
Soybean oil meal	227.74	209.51	147.85	122.33
Fish meal (Menhaden)	70.07	70.17	73.30	62.36
Bakery byproducts	40.04	40.10	41.88	41.57
Meat and Bone meal	12.41	12.27	5.24	5.20
Poultry byproduct meal	9.93	8.82	3.66	3.64
Feather meal	2.48	2.96	1.50	1.56
Fat	9.71	14.23	23.35	17.88
Dicalcium phosphate	6.68	5.35	6.21	6.62
Ground limestone	4.67	4.85	4.74	5.73
Salt	1.02	1.20	1.39	1.58
Choline	1.10	1.20	1.58	1.56
DL methionine	2.21	1.71	1.68	1.25
Trace mineral mix	.50	.50	.54	.53
Vitamin premix*	2.51	2.51	2.75	2.70
Total	1000.00	1000.00	1000.00	1000.00
Calculated analysis:				
Protein (%)	23.06	22.21	18.24	16.79
Lysine (%)	1.31	1.25	1.00	.89
Total sulfur amino acids (%)	1.00	.93	.82	.72
Metabolizable Energy, kcal/kg	3036	3080	3190	3190

*Includes coccidiostat for all formulations except withdrawal.

Table 2. Low amino acid diets.

	Starter	Grower	Finisher	With-drawal
Ingredients (kg)				
Corn	609.84	662.35	761.32	759.04
Soybean oil meal	226.03	195.49	123.44	106.40
Fish meal (Menhaden)	70.07	70.07	72.61	62.10
Bakery byproducts	40.05	40.04	14.28	41.41
Meat and Bone meal	13.85	5.01	5.19	5.18
Poultry byproduct meal	11.09	3.51	3.64	3.62
Feather meal	2.77	1.50	1.55	1.55
Fat	8.81	2.80	--	1.55
Dicalcium phosphate	6.68	7.35	4.32	6.08
Ground limestone	4.67	4.85	5.72	5.90
Salt	1.02	1.04	2.04	1.60
Choline	1.10	1.30	1.66	1.60
DL methionine	1.20	1.70	1.04	.76
Trace mineral mix	.50	.50	.53	.53
Vitamin premix*	2.51	2.51	2.67	2.68
Total	1000.00	1000.00	1000.00	1000.00
Calculated analysis:				
Protein (%)	23.05	21.02	17.50	16.31
Lysine (%)	1.31	1.18	.94	.84
Total sulfur amino acids (%)	.90	.91	.70	.66
Metabolizable Energy, kcal/kg	3036	3036	3080	3124

*Includes coccidiostat for all formulations except withdrawal.

starter, grower, finisher and withdrawal diets starting on 1, 22, 32 and 44 days of age, respectively. All diets were formulated to have adequate levels of all other essential nutrients (NRC, 1977). Each pen was equipped with either one or two tube feeders with pan(s) measuring 35 cm in diameter. This provided either 1.47 or 2.94 cm of feeding space per bird, respectively.

Experiment 2 (Exp 2). In the second experiment two light regimes similar to those described for Exp 1 were used in conjunction with two ambient temperature and two relative humidity levels in a factorial arrangement. Each treatment was replicated four times.

Temperature in all pens was maintained at 29° C for the first seven days. Temperature in one-half the pens was gradually reduced from 29 to 26° C from 8 to 36 days of age and was held constant for the remainder of the experiment. Temperature in the other 16 pens was gradually reduced from 29 to 18° C during this period and then held constant. Actual temperatures were recorded daily with high-low thermometers (measured 120 cm above the litter) and averaged on a weekly basis in each block of four pens and are presented in Figure 1.

Relative humidity was designed to be 70% in one-half the pens and 40% in the remaining pens after the first week of age. Measurements for this parameter were made daily with a sling psychrometer and averaged on a weekly basis in each block of four pens (Figure 2). Steam was used to increase the humidity in the high moisture pens. After the brooding period, it became extremely difficult to maintain the high humidity regime in combination with proper ventilation.

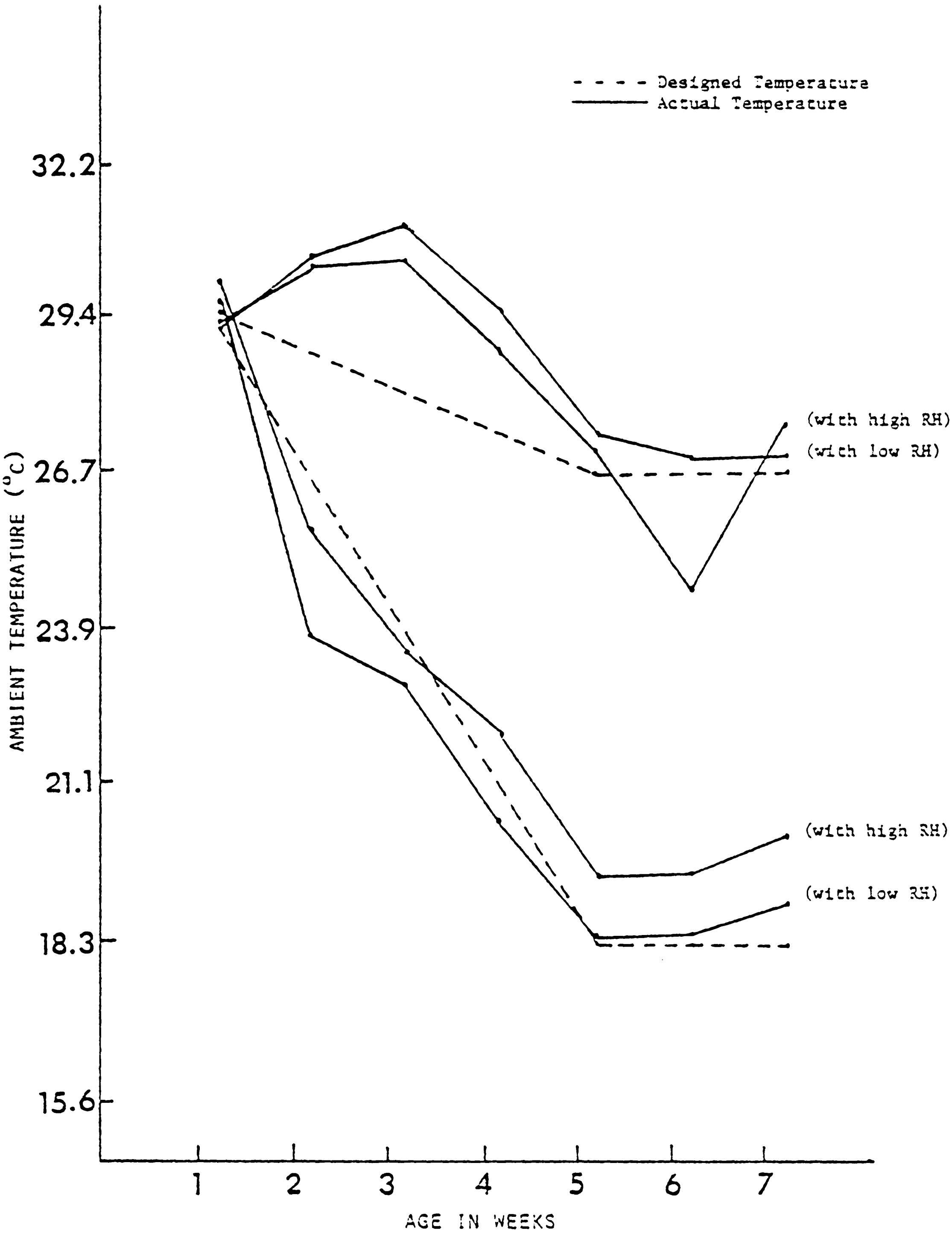

Figure I. Designed and actual ambient temperatures in the high and low treatment groups.

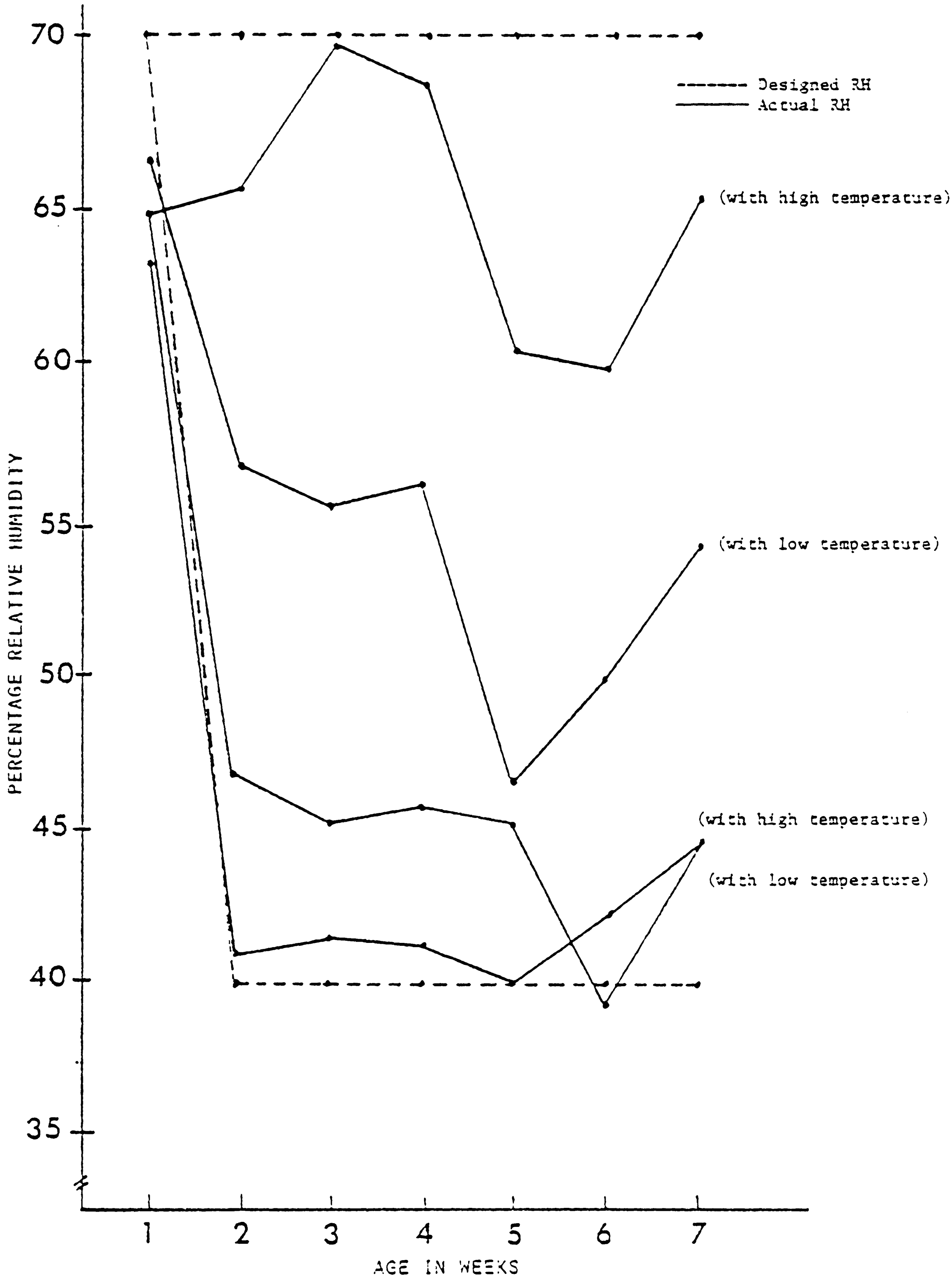

Figure 2. Designed and actual relative humidities in the high and low treatment groups.

Excessive condensation developed in those units which could have been detrimental to bird health. Therefore, a decision was made after four weeks of age to reduce the relative humidity in the high humidity pens. Generally, the low relative humidity pens were maintained within five percent of the desired settings.

Data collection and analyses. Birds were individually weighed to the nearest 5 grams at 28 and 49 days of age. Feed efficiency was calculated, after adjusting for mortality on a pen basis at these times. At the conclusion of each experiment, five birds were randomly selected from each pen, weighed, sacrificed, defeathered and eviscerated. The abdominal fat pad (not including fat attached to viscera) was removed, weighed and expressed as a percentage of live body weight. Fat samples from Exp 1 were further analyzed by an ether extraction procedure, with percentage lipids determined and used as an indirect measure of fat cell size (AOAC, 1975).

Leg abnormalities were observed and subjectively scored at 49 days of age to determine incidence and severity. Incidence was defined as the percentage of birds in each pen that demonstrated reluctance to move or obviously crippled legs. Severity provided a numerical score depicting the seriousness of the leg involvement. The severity scoring procedure had four levels; with a score of one representing a bird with no observable leg abnormalities; two having slight difficulty in movement due to hip, hock and/or foot defects; three having moderate difficulty in movement; and four having severely affected movement due to gross defects.

Atmospheric ammonia and litter moisture were measured weekly during Exp 2. Ammonia level was measured in parts per million (ppm) in each block of four pens (with each pen separated by wire partitions) with a Unico precision gas detection cylinder equipped with disposable ammonia sensing tubes. Percentage litter moisture was also determined weekly by using an oven drying technique (AOAC, 1975).

Treatment differences in body weight and abdominal fat pad size (expressed as a percentage of live weight) were determined on an individual bird basis by analysis of variance at 28 (body weight only) and 49 days of age. The statistical model was:

$$Y_{ijklm} = \mu + L_i + D_j + F_k + R_l + (LD)_{ij} + (LF)_{ik} + (LR)_{il} + (DF)_{jk} + (DR)_{jl} + (FR)_{kl} + (LDF)_{ijk} + (LDR)_{ijl} + (LFR)_{ikl} + (DFR)_{ikl} + (LDFR)_{ijkl} + e_{ijklm}$$

Where i = 1,2 light regimes, j = 1,2 diets (Exp 1) or 1,2 temperatures (Exp 2), k = 1,2 feeding spaces (Exp 2) or 1,2 relative humdiities (Exp 2), l = 1,2....4 replications and m = 1,2...n individuals.

Feed efficiency, expressed as a gram of body weight per grams of feed consumed, and percentage leg abnormalities were measured at 28 (feed efficiency only) and 49 days of age. Analysis of variance, conducted on a light-diet-feeding space-replicate (Exp 1) or a light-temperature-relative humidity-replicate (Exp 2) subclass basis, was used to determine differences among treatments for these traits. When significant differences were found, means within treatments were separated by Duncan's multiple range test (Duncan , 1955).

RESULTS AND DISCUSSION

Experiment 1

Analyses of variance with corresponding mean squares for broiler body weights and feed efficiencies at 28 and 49 days of age are presented in Tables 3 and 4, respectively. Furthermore, analyses of variance with corresponding mean squares for percentage abdominal fat, percentage ether extract and the incidence and severity of leg abnormalities at 49 days of age are presented in Table 5 and 6, respectively.

Light. Male broilers were significantly heavier with similar feed efficiencies under intermittent light (IL) when compared with continuous light (CL) at 28 and 49 days of age (Table 7). Broiler body weights were 17 and 41 grams greater at 28 and 49 days of age, respectively, for birds provided the intermittent photoperiods. These results are in agreement with many previous investigations that suggested birds given intermittent periods of feeding and resting grow more rapidly than those allowed to ingest nutrients on an *ad libitum* basis. The periodic eating and resting allows for intense consumption during the light or feeding period, and then provides for a period of reduced activity and energy expenditure during darkness (Romsos and Leveille, 1977).

Diet. Birds provided the high amino acid diets had four and three percent greater body weights at 28 and 49 days of age, respectively, when compared with those fed the lower amino acid diets (Table 8). Furthermore, the birds receiving the high amino acid diets had a

Table 3. Analysis of variance of body weight at 28 and 49 days of age.

Source of variation	df[1]	M.S. 28 days	M.S. 49 days
Total	2367		
Light (L)	1	216410**	1173226**
Diet (D)	1	812905**	3661092**
Feeder (F)	1	175092**	671599**
Replication (R)	3	119891**	412669**
L x D	1	5696	7514
L x F	1	9954	96306
D x F	1	47473*	890207**
L x D x F	1	95062**	151627
error	2357		64180

* $P \leq .05$, ** $P \leq .01$

[1] Degrees of freedom changed at 49 days due to mortality.

Table 4. Analysis of variance of feed efficiency at 28 and 49 days of age.

Source of variation	df	M.S. 28 days	M.S. 49 days
Total	31		
Light (L)	1	.00140	.00017
Diet (D)	1	.00074	.00087*
Feeder (F)	1	.00071	.00002
Replication (R)	3	.00091	.00017
L x D	1	.00072	.00013
L x F	1	.00001	.00001
D x F	1	.00034	.00001
L x D x F	1	.00025	.00001
error	21	.00043	.00017

* $P \leq .05$

Table 5. Analysis of variance of percentage abdominal fat and percentage ether extract at 49 days of age.

Source of variation	df	M.S. 49 days: Abdominal fat (%)	M.S. 49 days: Ether extract (%)
Total	95		
Light (L)	1	0.37001	0.00263
Diet (D)	1	2.31260*	0.00017
Feeder (F)	1	0.00201	0.00050
Replication (R)	3	0.38596	0.00086
L x D	1	0.12760	0.00005
L x F	1	0.00427	0.00121
D x F	1	0.41870	0.00030
L x D x F	1	0.64354	0.00019
error	86	0.32069	0.00075

* $P \leq .05$

Table 6. Analysis of variance of incidence and severity of leg abnormalities at 49 days of age.

Source of variation	df	M.S. 49 days: Incidence	M.S. 49 days: Severity
Total	31		
Light (L)	1	163.96013**	0.13871**
Diet (D)	1	10.84789	0.01248
Feeder (F)	1	43.53089*	0.00703
Replication (R)	3	3.59745	0.00226
L x D	1	5.51883	0.00103
L x F	1	20.54148	0.01396
D x F	1	0.09287	0.00086
L x D x F	1	3.33489	0.00001
error	21	9.83687	0.00724

* $P \leq .05$, ** $P \leq .01$

Table 7. The effect of light regimes on body weight and feed efficiency at 28 and 49 days of age.

Days of age	Light Regimes	Body weight (g)	Feed efficiency
28	Continuous	964 $\pm 121^{a}$	.662 $\pm .024^{a}$
	Intermittent	981 $\pm 100^{b}$	.678 $\pm .020^{a}$
49	Continuous	2305 $\pm 273^{a}$	.542 $\pm .011^{a}$
	Intermittent	2346 $\pm 243^{b}$	.537 $\pm .015^{a}$

[a,b]Means within an age group followed by a different superscript differ significantly ($P \leq .05$)

Table 8. The effect of diet on body weight and feed efficiency at 28 and 49 days of age.

Days of age	Diet	Body weight (g)	Feed efficiency
28	Low amino acid	955 $\pm 119^{a}$	.664 $\pm .022^{a}$
	High amino acid	991 $\pm 99^{b}$	.676 $\pm .024^{a}$
49	Low amino acid	2286 $\pm 273^{a}$	.545 $\pm .016^{b}$
	High amino acid	2365 $\pm 238^{b}$	.533 $\pm .006^{a}$

[a,b]Means within an age group followed by a different superscript differ significantly ($P \leq .05$)

Table 9. The effect of feeder space on body weight and feed efficiency at 28 and 49 days of age.

Days of age	Feeding space (cm)	Body weight (g)	Feed efficiency
28	2.94	980 $\pm 115^{a}$	.665 $\pm .027^{a}$
	1.47	966 $\pm 107^{b}$	.675 $\pm .017^{a}$
49	2.94	2339 $\pm 262^{a}$	.538 $\pm .012^{a}$
	1.47	2312 $\pm 255^{b}$	.540 $\pm .014^{a}$

[a,b]Means within an age group followed by a different superscript differ significantly ($P \leq .05$)

significantly higher feed efficiency at 49 days of age. These data indicate that broilers can be grown at a faster rate and more efficiency when given increased levels of these amino acids.

Feeding space. Broilers provided 2.94 cm of feeding space were 1.4 and 1.2% heavier at 28 and 49 days of age, respectively, when compared with chickens given one-half that amount of space (Table 9). Similar feed efficiencies were noted under the two feeding space regimes.

Doubling feeding space probably decreased the competition at the feeder(s) among birds. This allowed birds to consume more feed in pens with increased feeding space. Both Malone *et al.* (1980b) and Weaver *et al.* (1982) reported similar findings. They found the increasing feeding space resulted in corresponding increases in body weight.

Diet x feeding space. A significant diet x feeding space interaction was noted at 28 and 49 days of age (Figures 3 and 4). Increasing the feeding space from 1.47 to 2.94 cm per bird had little affect on the body weight of broilers fed the high amino acid diets. However, under the low amino acid regime a significant increase in weight was observed when increased feeding space was provided. These findings indicate that birds under restricted feeding space situations require a higher level of amino acids in order to maintain growth performance. Weaver *et al.* (1982) reported that when total nutrient density was increased with feeding space levels similar to those used in this experiment, no diet x feeding space interaction occurred.

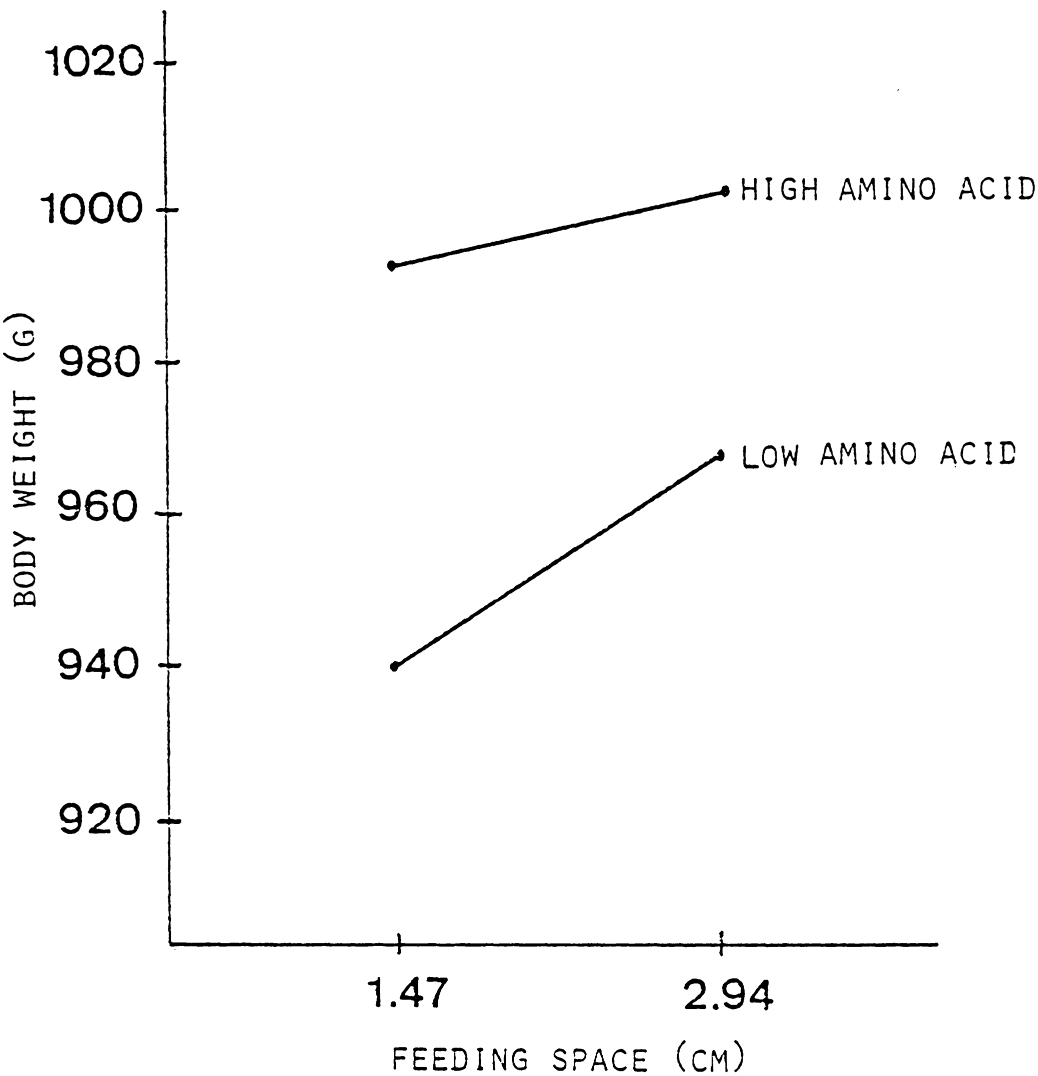

Figure 3. The effects of diet and feeding space on body weight at 28 days of age.

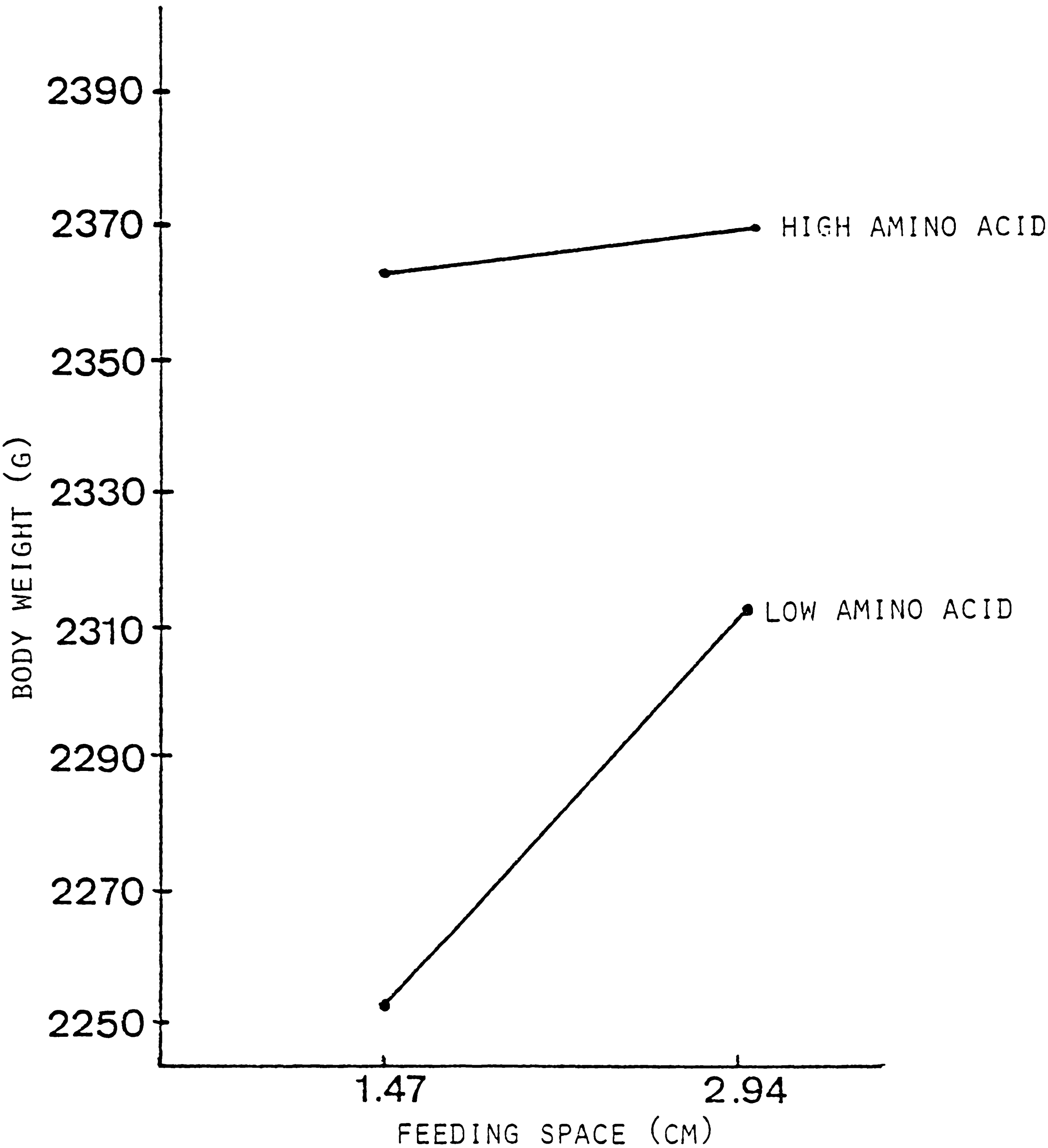

Figure 4. The effects of diet and feeding space on body weight at 49 days of age.

However, they did not report how protein consumption was influenced by these treatments.

Light x feeding space. Weaver *et al.* (1982) reported a significant light x feeding space interaction when these two variables were provided at levels similar to those used in this experiment. Even though this interaction was not significant (P = 0.063) in this experiment, the trend observed between these variables was similar to those previously reported (Figure 5). Under IL broilers appeared to require more feeding space than birds provided CL. When given this increased feeding space, broilers on IL had heavier body weights. However, when feeding space was more restricted, body weights tended to be similar under the two light regimes.

Light x diet. No significant interaction was found between light and diet at 28 and 49 days of age. These data are consistent with those of Cherry *et al.* (1978), Malone *et al.* (1980a) and Weaver *et al.* (1982) who reported that higher density rations failed to improve broiler weights when reared under IL. These findings conflict with those of Buckland *et al.* (1971) who suggested that diets with lower levels of protein were partially responsible for decreased bird performance under IL when compared with CL.

Light x diet x feeding space. A significant light x diet x feeding space interaction was observed at 28, but not at 49 days of age. Body weight was the lowest (941 and 946 grams, respectively) under both lighting regimes when birds were provided 1.47 cm feeding space and low amino acid diets (Table 10). Doubling feeding space

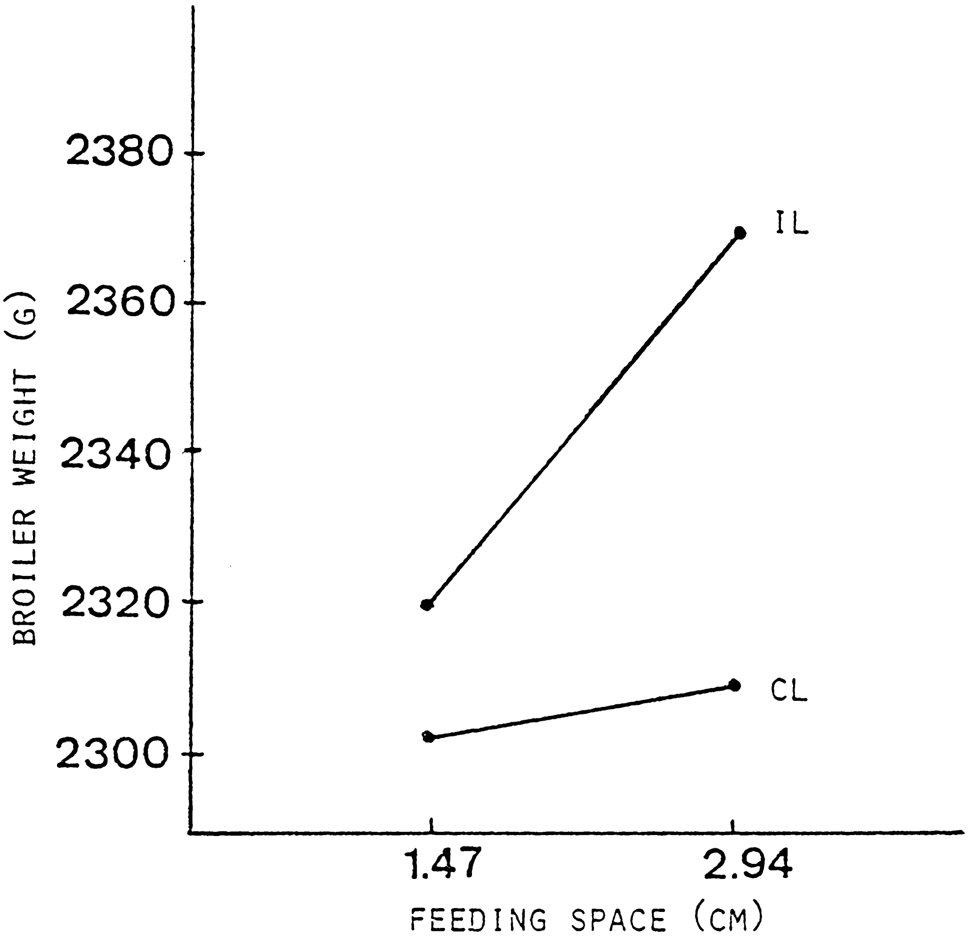

Figure 5. The effects of light regime and feeding space on body weight at 49 days of age.

Table 10. The effects of light, diet and feeding space on body weight at 28 days of age.

Feeding space (cm)	Continuous light: Low amino acid diets	Continuous light: High amino acid diets	Intermittent light: Low amino acid diets	Intermittent light: High amino acid diets
1.47	946.19 ±126[a]	970.98 ±101[b]	940.58 ±107[a]	1002.46 ±88[d]
2.94	949.70 ±137[a]	993.91 ±113[cd]	983.20 ±96[bc]	1002.37 ±95[d]

a,b,c,d Means bearing similar superscripts are not significantly different at $P \leq .05$.

Table 11. The effects of light, diet and feeding space on body weight at 49 days of age.

space (cm)	Continuous light: Low amino acid diets	Continuous light: High amino acid diets	Intermittent light: Low amino acid diets	Intermittent light: High amino acid diets
1.47	2230.65 ±300[a]	2347.89 ±252[a]	2266.41 ±265[a]	2377.03 ±212[a]
2.94	2292.12 ±289[a]	2329.65 ±232[a]	2340.12 ±229[a]	2399.49 ±242[a]

significantly increased body weight for broilers fed this diet under IL, but not CL. It would appear from these findings that broiler body weights can be improved under IL when low density rations are fed by increasing the amount of feeding space.

Birds provided increased feeding space and CL were heavier under the higher versus the lower amino acid diets. This trend was not true for broilers under IL. The increase in body weight under the high versus the low feeding space regime when provided CL and high amino acid diets is difficult to explain, as no improvement in weight was observed under similar light and feeding space treatments and low amino acid diets.

The biological significance of this second order interaction at 28 days of age must be questioned, since the same interaction was not significant at market age (Table 11). If feeding space was truly restrictive under the IL regime and the low amino acid diets, one would expect this condition to continue and possibly become worse as the birds grow older.

Abdominal fat. Broilers fed the high amino acid diet had significantly more abdominal fat than birds on the low amino acid diet when processed at 49 days of age (Table 12). These findings are inconsistent with previous investigations that suggested high protein diets resulted in increased carcass protein and decreased carcass fat with little effect on gain (Rand *et al.*, 1957; Spring and Wilkinson, 1957; Summers *et al.*, 1965; Griffiths *et al.*, 1977; Hargis and Creger, 1980; Holsheimer, 1980). Perhaps this increase in abdominal fat is associated with the improved growth rates on the high amino acid diets even

Table 12. The effects of light, diet, and feeding space on percentage abdominal fat and percentage ether extract at 49 days of age.

Treatments	Abdominal fat (%)[1]	Ether extract (%)
Light regime		
Continuous	1.96 ±.51[a]	.89 ±.03[a]
Intermittent	2.08 ±.65[a]	.90 ±.03[a]
Diet		
Low amino acid	1.87 ±.51[a]	.89 ±.03[a]
High amino acid	2.18 ±.62[b]	.89 ±.03[a]
Feeding space (cm)		
1.47	2.03 ±.56[a]	.89 ±.03[a]
2.94	2.02 ±.61[a]	.89 ±.03[a]

[1] Percentage of live weight.
[2] Percent lipid in abdominal fat pad.
[a,b] Means followed by different superscripts differ significantly ($P \leq .05$).

though the figures were corrected for body weight. The actual differences in abdominal fat between these dietary treatments were only 0.31%, which is numerically small even though significantly different.

Neither light nor feeding space had any effect on the percentage abdominal fat measured in this experiment. The similarity of percentage abdominal fat between light regimes is inconsistent with the findings of Buckland *et al.* (1971), Deaton *et al.* (1978) and Malone *et al.* (1980a), as they reported increased levels of abdominal fat from birds grown under IL.

No differences were noted among any of the treatments for ether extractions, indicating that fat cell size was not affected by the variables imposed in this experiment (Table 12). No significant interactions were observed for percentage abdominal fat or percentage ether extraction.

Leg abnormalities. Light significantly influenced the incidence and severity of leg abnormalities of male broilers. The birds provided IL had 48% fewer leg defects and 47% less severe leg abnormalities than birds given continuous illumination (Table 13). These observations support previous findings by Buckland *et al.* (1973 and 1976). They reported birds on CL had a higher percentage of leg abnormalities than those grown on IL. Furthermore, they reported that male birds had twice as many leg defects as females, which these investigators partially associated with the increased body size of the males. The increased incidence and severity of leg abnormalities cannot be explained through body weight in this experiment, as broilers

Table 13. The effect of light, feeding space, and dietary amino acids on incidence and severity of leg abnormalities at 49 days of age.

Treatments	Incidence (%)		Severity	
Light regime				
Continuous	9.75	$\pm 3.68^{a}$	1.27	$\pm .10^{b}$
Intermittent	5.12	$\pm 2.63^{b}$	1.13	$\pm .06^{a}$
Feeding space (cm)				
1.47	6.25	$\pm 3.07^{a}$	1.18	$\pm .09^{a}$
2.94	8.63	$\pm 4.41^{b}$	1.21	$\pm .12^{a}$
Diet				
Low amino acid	8.24	$\pm 3.96^{a}$	1.22	$\pm .11^{a}$
High amino acid	6.53	$\pm 3.81^{a}$	1.17	$\pm .10^{a}$

[a,b] Means followed by different superscripts differ significantly ($P \leq .05$).

under IL were significantly heavier than birds on CL. Possibly the differences can be partially explained through the observed difference in activity under the two lighting patterns. Broilers provided CL tended to be extremely docile during the latter portion of the growing cycle. Those given IL were observed to be more active during the time lights were on. The intermittent periods of light appeared to stimulate the broilers to move about and feed. The exercise periods under IL apparently provided these birds with a regime conducive to strong leg development.

Pens that provided birds with 1.47 cm of feeding space had 28% fewer birds demonstrating leg abnormalities than pens with 2.94 cm of feeding space. No difference in the severity of leg problems was noted between these feeding space levels. Perhaps the birds given more feeder space had to compete less at the feeder. Therefore, these birds received less (and/or strenuous) exercise which resulted in more leg problems. Additionally, birds given more feeder space were heavier, which also could have contributed to the increase in leg defects.

The amino acid levels used in this investigation had no significant effect on the severity or incidence of leg abnormalities at market age (Table 13). No significant interactions were observed in regard to leg abnormalities.

Experiment 2

Analyses of variance with the corresponding mean squares for broiler body weights and feed efficiencies at 28 and 49 days of age are presented in Table 14 and 15, respectively. Furthermore, analyses of variance with corresponding mean square for percentage abdominal fat and the incidence and severity of leg abnormalities are presented in Tables 16 and 17, respectively.

Light. When male broilers were given IL, they had improved feed efficiency at 28 days and heavier body weight at 49 days of age, when compared with similar birds provided continuous illumination (Table 18). At market age, birds provided IL were 2.9% heavier with a similar feed efficiency to those with CL.

These findings are in agreement with previous investigations where gain and/or feed efficiency improved with the use of IL. However, previous studies indicated that bird performance with IL only improved when ample feeding space was provided (Malone *et al.*, 1980 and Weaver *et al.*, 1982). Contrastingly, the results in this experiment were noted when all birds were provided 1.47 cm of feeding space per bird. This feeding space was considered restrictive by earlier investigators. No explanation is offered for this apparent contradiction.

Ambient temperature. At four weeks of age birds given the low (29 to 18° C) and high (29 to 26° C) temperature regimes had similar body weights (Table 19). However, birds on the high temperature

Table 14. Analysis of variance of body weight at 28 and 49 days of age.

Source of variation	df[1]	M.S. 28 days	M.S. 49 days
Total	2116		
Light (L)	1	10559	5551082**
Temperature (T)	1	431	9692899**
Relative humidity (H)	1	88824**	6128
Replication (R)	3	39871**	93115
L x T	1	63252**	12746
L x H	1	23532	280937*
T x H	1	86413**	394616**
L x T x H	1	4255	20620
error	2087	7537	48168

* $P \leq .05$, ** $P \leq .01$

[1] Degrees of freedom changed at 49 days due to mortality

Table 15. Analysis of variance of feed efficiency at 28 and 49 days of age.

Source of variation	df	M.S. 28 days	M.S. 49 days
Total	31		
Light (L)	1	.00079*	.00049
Temperature (T)	1	.00495**	.00027
Relative humidity (H)	1	.00006	.00020
Replication (R)	3	.00009	.00020
L x T	1	.00009	.00200
L x H	1	.00025	.00001
T x H	1	.00003	.00196
L x T x H	1	.00005	.00030
error	21	.00015	.00053

** $P \leq .01$

Table 16. Analysis of variance of percentage abdominal fat at 49 days of age.

Source of variation	df	M.S. 49 days
Total	148	
Light (L)	1	2.77439
Temperature (T)	1	11.18390
Relative humidity (H)	1	10.43335
Replication (R)	3	15.72794
L x T	1	11.70313
L x H	1	13.76367
T x H	1	24.29588
L x T x H	1	20.35745
error	138	14.39997

Table 17. Analysis of variance of incidence and severity of leg abnormalities at 49 days of age.

		M.S. 49 days	
Source of variation	df	Incidence	Severity
Total	29		
Light (L)	1	98.22273**	0.14794**
Temperature (T)	1	0.01023	0.00853
Relative humidity (H)	1	8.60114	0.01556
Replication (R)	3	5.82143	0.01147
L x T	1	5.06250	0.00473
L x H	1	1.17361	0.01490
T x H	1	1.56250	0.00428
L x T x H	1	5.58034	0.00219
error	19	5.42293	0.01093

** $P \leq .05$

Table 18. The effect of light regimes on body weight and feed efficiency at 28 and 49 days of age.

Days of age	Light regimes	Body weight (g)	Feed efficiency
28	Continuous	936 ±93[a]	.668 ±.018[b]
	Intermittent	940 ±82[a]	.678 ±.016[a]
49	Continuous	2196 ±252[a]	.668 ±.018[a]
	Intermittent	2285 ±209[b]	.678 ±.016[a]

a,b Means within an age group followed by different superscripts differ significantly ($P \leq .05$)

Table 19. The effect of ambient temperature on body weight and feed efficiency at 28 and 49 days of age.

Days of age	Ambient temperature	Body weight (g)	Feed efficiency
28	Low (29 to 18°C)	939 ±92[a]	.685 ±.014[b]
	High (29 to 26°C)	938 ±83[a]	.661 ±.011[a]
49	Low (29 to 18°C)	2313 ±240[b]	.685 ±.014[a]
	High (29 to 26°C)	2173 ±214[a]	.661 ±.011[a]

a,b Means within an age group followed by different superscripts differ significantly ($P \leq .05$)

Table 20. The effect of relative humidity on body weight and feed efficiency at 28 and 49 days of age.

Days of age	Relative humidity	Body weight (g)	Feed efficiency
28	Low (<40%)	932 ±88[a]	.672 ±.018[a]
	High (70%)	944 ±87[b]	.674 ±.018[a]
49	Low (<40%)	2231 ±231[a]	.672 ±.018[a]
	High (70%)	2244 ±241[a]	.674 ±.018[a]

a,b Means within an age group followed by different superscripts differ significantly ($P \leq .05$)

regime for this period had significantly higher feed efficiencies than broilers given the low temperature. By the time the birds had reached 49 days of age, those receiving the low temperature treatment weighed 6.1% more than broilers under the high temperature regime (Table 19). Feed efficiencies at marketing were similar for broilers under these temperature treatments.

The depressed body weight gains at market age under the high temperature agrees with findings reported in previous investigations (Deaton *et al.*, 1973; Cerniglia *et al.*, 1976). After the brooding period, higher ambient temperatures (above 25° C) seemed to be detrimental to bird performance. Deaton *et al.* (1970) reported that as ambient temperature increased from 7.2 to 29.4° C, feed efficiency also increased while body weight decreased. With further increases in temperature (above 29.4° C) feed efficiency tended to decrease with total feed consumed per bird decreasing during the entire period. The improved feed efficiency found in this experiment at 28 days of age under high temperature agrees with the findings of these investigators.

As temperature increases, the bird first becomes more efficient in utilizing feedstuffs, as less is required to maintain body temperature. Then as temperature continues to increase and feed consumption to decrease, nutrients required for body maintenance make up an increasingly greater portion of the ingested nutrients, leaving less for growth. Finally, a point is reached when feed efficiency starts to decrease. The feed efficiencies under the two temperature regimes were similar (Table 19) at 49 days of age in this experiment. This possibly indicated that efficiency has already plateaued and started to decrease under the higher temperature regime.

Relative humidity. Broilers grown at 70% relative humidity (RH) through four weeks of age had significantly heavier body weights and similar feed efficiencies when compared with birds on the low relative humidity regime (Table 20). The young birds possibly became dehydrated under the low RH treatment, accounting for the reduction in weight among broilers in the drier environment. However, no differences in percentage liveability were noted between these RH regimes.

Relative humidity did not significantly affect broiler body weight or feed efficiency at 49 days of age. These findings agree with investigations by Winn and Godfrey (1967) which reported that broiler body weight and feed efficiency were not signficiantly affected when RH was maintained between 30 and 93% with ambient temperature at 18^{o} C after four weeks of age.

Light x temperature. A significant interaction between light and temperature for body weight was noted at four weeks of age (Figure 6), but not at 7 weeks of age. Broilers provided IL were heavier under the high temperature regime, while birds under CL weighed more when provided a low temperature. Broilers under IL were observed to be much more active during the light periods and then assumed a more docile or resting posture during the dark periods. Possibly broilers could cope with the higher temperatures better under IL because of these scheduled rest periods. Ota (1967) reported that birds produce 25% less heat in

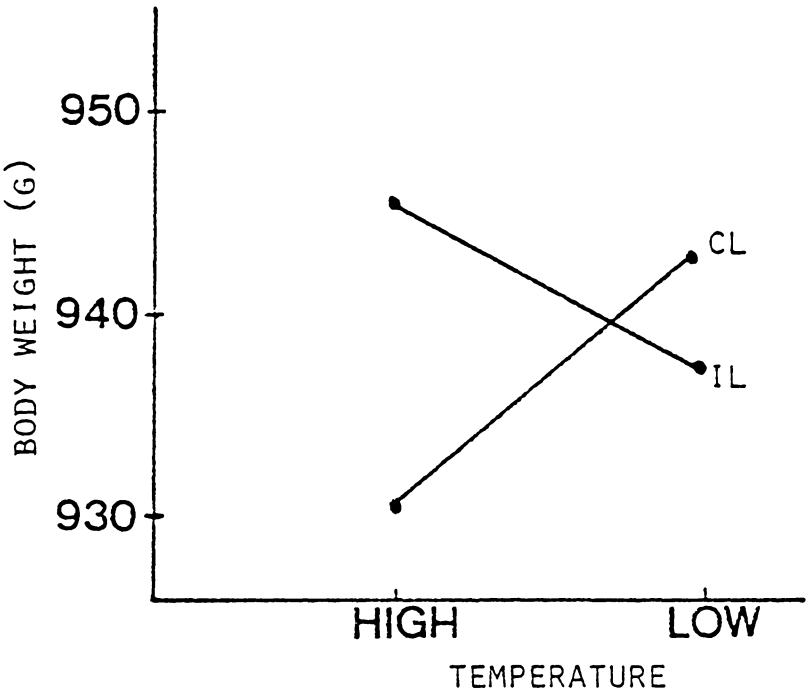

Figure 6. The effects of light and temperature on body weight at 28 days.

dark than light periods which may explain the improved broiler performance under IL and high temperature.

When broilers were placed in the cooler environment, the IL birds weighed less than those under CL (Figure 6). Perhaps under the low temperature regime, the intermittent periods of darkness were detrimental to growth, as body temperature was possibly more difficult to maintain during these periods. Consequently, a larger portion of the ingested nutrients had to be used for body maintenance under low temperature and IL.

Temperature x relative humidity. The effects of temperature x relative humidity on broiler body weight were significant at 28 and 49 days of age (Figures 7 and 8). Relative humidity had no effect on body weight under the high temperature treatment at four weeks of age. However, under the low temperature treatment, broilers grown with high RH had improved body weight when compared with birds provided low RH. These data are in agreement with those of Milligan and Winn (1964) who noted that growth performance was improved when birds were given low temperature and high RH over those provided high temperature and high RH.

At 49 days of age, the birds given high temperature and high RH had the lowest body weight, while those provided low temperature and high RH continued to have the heaviest weights (Figure 8). At the older age the high temperature appeared to be detrimental to performance, especially when in combination with the high RH. These findings are consistent with those of Winn and Godfrey (1967) who reported that

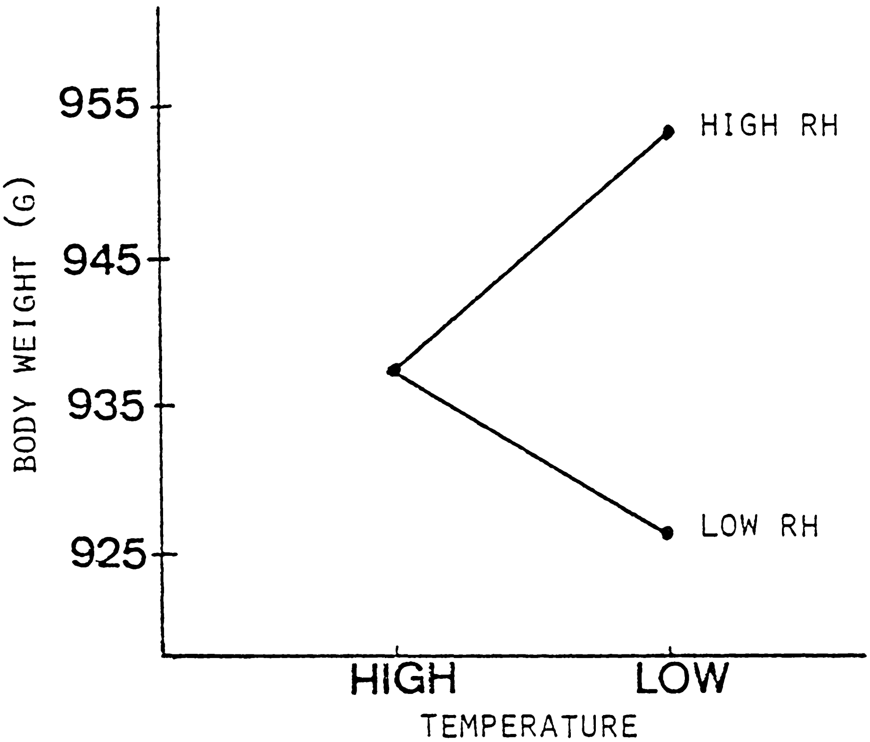

Figure 7. The effects of temperature and relative humidity on body weight at 28 days of age.

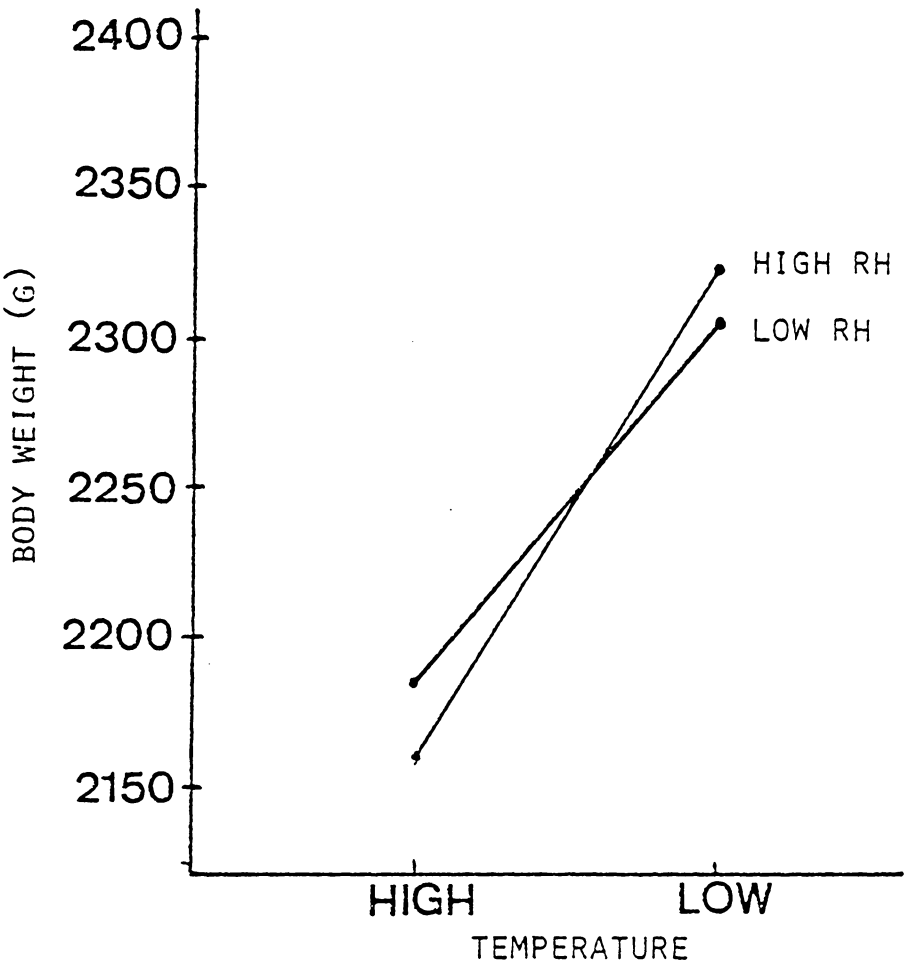

Figure 8. The effects of temperature and relative humidity on body weight at 49 days of age.

when ambient temperature exceeded 27^{o} C, high levels of humidity depressed gains. These findings further substantiate the detrimental additive effect of high temperature in combination with high RH.

Dramatic increased in atmospheric ammonia were recorded in the high temperature, high RH pens during the later stages of this experiment (Figure 9). These elevated levels of ammonia could have further contributed to the poorer bird performance in these pens. Quarles and Kling (1974) and Reece *et al.* (1980 and 1981) reported that when atmospheric ammonia was raised from 0 to 50 ppm, body weight was reduced by as much as eight percent. Quarles and Kling (1974) also reported a significant decrease in feed efficiency under the higher levels of ammonia.

Light x relative humidity. An unexplained light x relative humidity interaction for body weight was noted at 49 days of age (Figure 10).

Light x temperature x relative humidity. No significant light x temperature x relative humidity interaction was observed at 28 or 49 days of age (Table 21 and 22).

Abdominal fat. Light, ambient temperature and relative humidity were found to have no significant effect on percentage abdominal fat in male broilers at 49 days of age (Table 23). Numerically, the birds under IL had less abdominal fat than birds given CL. This is contrary to previous investigations that reported greater abdominal fat when birds received IL. Large variations in percentage abdominal fat were observed among birds within treatments, which is noted by the large

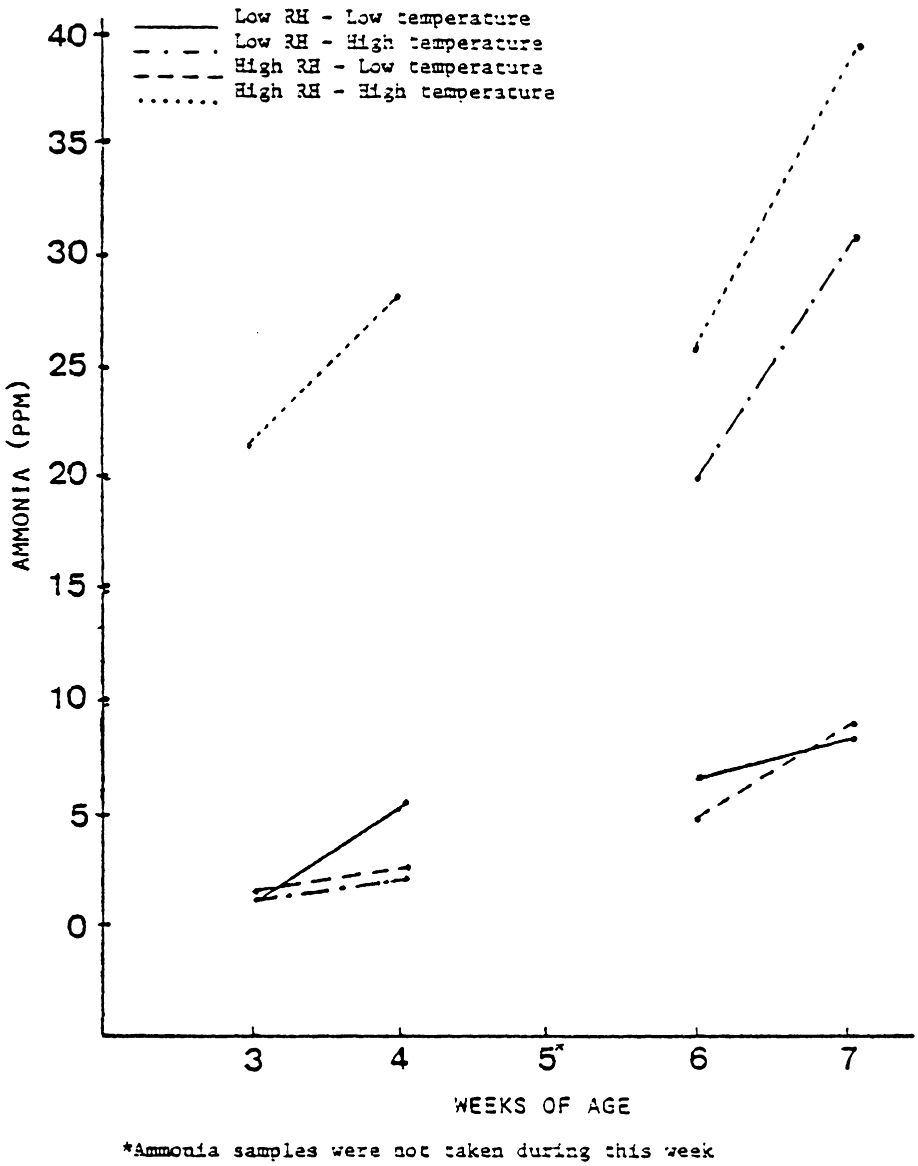

Figure 9 . Ammonia levels under high and low temperature and high and low relative humidity regimes.

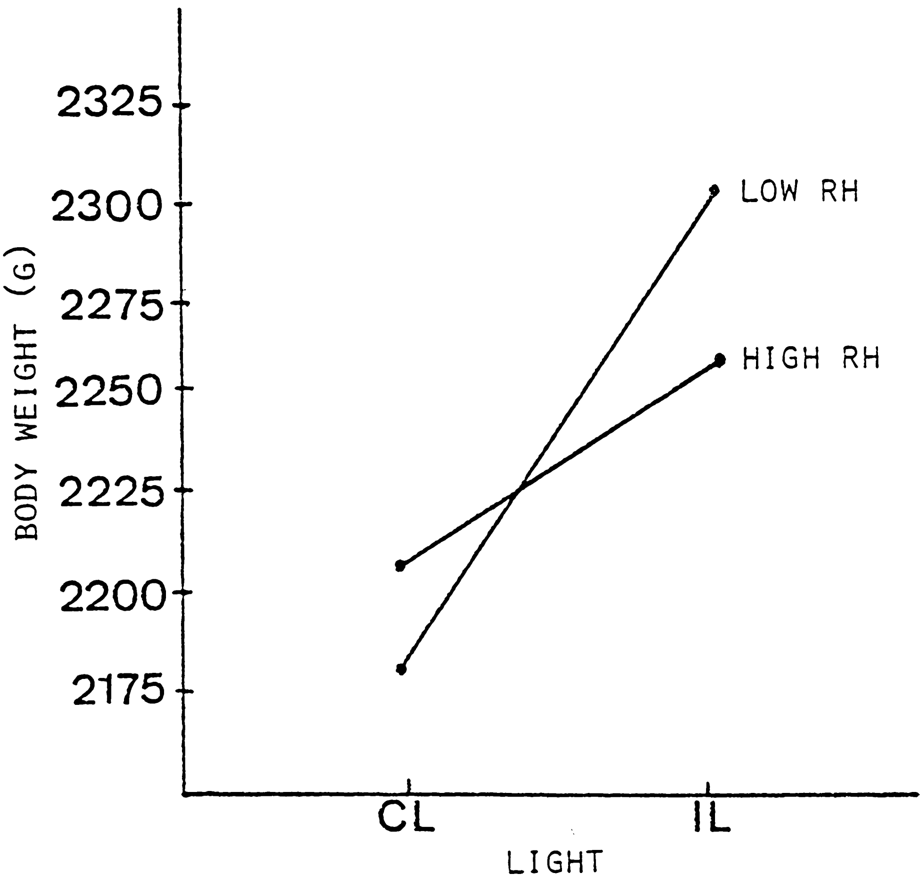

Figure 10. The effects of light and relative humidity on body weight at 49 days of age.

Table 21. The effects of light, ambient temperature and relative humidity on body weight at 28 days of age.

Ambient temperature	Continuous light Low RH (40%)	Continuous light High RH (70%)	Intermittent light Low RH (40%)	Intermittent light High RH (70%)
Low (29 to 18°C)	933.96 ±102[a]	949.42 ±92[a]	918.81 ±84[a]	952.25 ±86[a]
High (29 to 26°C)	932.20 ±84[a]	928.76 ±93[a]	942.93 ±80[a]	946.92 ±75[a]

Table 22. The effects of light, ambient temperature and relative humidity on body weight at 49 days of age.

Ambient temperature	Continuous light Low RH (40%)	Continuous light High RH (70%)	Intermittent light Low RH (40%)	Intermittent light High RH (70%)
Low (29 to 18°C)	2242.99 ±268[a]	2303.71 ±235[a]	2358.13 ±202[a]	2379.89 ±224[a]
High (29 to 26°C)	2117.88 ±226[a]	2122.82 ±226[a]	2257.33 ±204[a]	2194.32 ±164[a]

Table 23. The effects of light regime, ambient temperature, and relative humidity on percentage abdominal fat at 49 days of age.

Treatments	Abdominal fat (%)
Light regime	
Continuous	2.65 ±5.20[a]
Intermittent	2.23 ±0.55[a]
Ambient temperature	
Low (29 to 18° C)	2.80 ±0.58[a]
High (29 to 26° C)	2.15 ±5.56[a]
Relative humidity	
Low (40%)	2.16 ±5.51[a]
High (70%)	2.78 ±0.63[a]

Table 24. The effects of light regime, ambient temperature, and relative humidity on incidence and severity of leg abnormalities at 49 days of age.

Treatments	Severity	Incidence (%)
Light regime		
Continuous	6.00 $\pm 2.63^{a}$	1.20 $\pm .14^{b}$
Intermittent	2.50 $\pm 1.61^{a}$	1.06 $\pm .03^{a}$
Ambient temperature		
Low (29 to 18° C)	4.57 $\pm 3.03^{a}$	1.12 $\pm .07^{a}$
High (29 to 26° C)	4.19 $\pm 2.74^{a}$	1.14 $\pm .15^{a}$
Relative humidity		
Low (40%)	4.00 $\pm 2.98^{a}$	1.15 $\pm .15^{a}$
High (70%)	4.69 $\pm 2.72^{a}$	1.11 $\pm .08^{a}$

[a,b] Means followed by different superscripts differ significantly ($P \leq .05$).

standard deviations. This is consistent with the findings of Becker *et al.* (1981), who reported large variations among birds for the weight of this tissue.

No significant interactions were noted between the treatments for percentage abdominal fat.

Leg abnormalities. When broilers were given IL, they had 58% lower incidences and 11.7% less severe leg abnormalities than birds provided CL (Table 24). These data agree with those of Exp 1 and of Buckland *et al.* (1973 and 1976) who observed fewer birds had leg defects when under IL. Birds provided CL tend to be more docile than birds on IL. The cycling on and off periods of light with IL provided the birds an opportunity to exercise on a regular basis. This periodically scheduled stimulation with IL apparently strengthened the leg of broilers under this regime.

Ambient temperature and relative humidity had no significant effect on incidence or severity of leg abnormalities as measured in this experiment (Table 24). No significant interactions were observed in regard to the incidence and severity of leg abnormalities.

SUMMARY AND CONCLUSIONS

Two experiments were conducted to determine the effects of light, dietary amino acid level, feeding space, ambient temperature and relative humidity on body weight and feed efficiency of broiler-type chickens. In addition, percentage abdominal fat and the incidence and severity of leg abnormalities were evaluated in both experiments. Each experiment contained 2400 male chickens of a commercial broiler cross, and were grown to 49 days of age. Three variables, with each replicated four times, were arranged in a factorial manner in each experiment.

Both experiments utilized continuous (CL) and intermittent light (IL) treatments. The intermittently lighted pens had one hour of light and two hours of darkness. The light intensity in all pens was started at 65 lux and gradually reduced to 3 lux at 28 days of age, and was then maintained at this level for the remainder of the experiment. In the first experiment, birds were also provided diets with two amino acid levels and feeding space of 1.47 and 2.94 cm per bird. Broilers in the second experiment were started under an ambient temperature regime of 29^{o} C (high) or 18^{o} C (low) by 36 days of age. Also, the birds in this experiment were reared under a relative humidity (RH) regime of 70%. At seven days of age birds in one-half the pens were placed on a regime receiving 40% RH, with the remaining pens staying on 70% regime. These temperature and RH regimes were maintained for the duration of the experiment.

The results from these experiments are summarized as follows:

1. In both experiments broilers exposed to IL were significantly heavier at 49 days of age with similar feed efficiencies when compared with birds receiving CL.

2. When fed the higher amino acid diets, broiler body weights were heavier at 28 and 49 days of age when compared to those on the lower amino acid diets. Furthermore, feed efficiency increased at 49 days of age on the high amino acid treatment.

3. Body weight improved at 28 and 49 days of age when feeding space was increased from 1.47 to 2.94 cm per birds. Feed efficiency was unaffected by the change in feeding space levels.

4. Birds on the high temperature regime had better feed efficiencies but similar body weights when compared with those on the lower regime at 28 days of age. However, at 49 days of age, broilers provided the lower temperature level weighed more than those grown on the high temperature regime, with the two regimes having similar feed efficiencies.

5. Through four weeks of age, broilers grown at 70% RH had better body weights and similar feed efficiencies when compared with birds on low RH. Forty-nine day body weights and feed efficiencies were unaffected by RH.

6. A significant diet x feeding space interaction was noted at 28 and 49 days of age. Increasing the feeding space from 1.47 to 2.94 cm per bird did not affect body weight on the high amino acid diets. However, when diets with the lower amino acid levels were fed, a

significant increase in weight was observed when feeding space was increased.

7. A significant interaction between light and temperature for body weight was noted at four weeks of age. Broilers provided IL were heavier under the high temperature regime, while birds under CL weighed more when provided the lower temperature.

8. The effect of temperature x relative humidity on broiler body weight was significant at 28 and 49 days of age. Relative humidity had no effect on body weight under the high temperature regime at four weeks of age. However, under the low temperature treatment, broilers grown with high RH had improved body weight when compared with birds provided low RH. At market age, the birds given high temperature and high RH had the lowest body weight, while those provided low temperature and high RH continued to have the heaviest weights.

9. Broilers fed the high protein diets had significantly more abdominal fat than birds on the low protein diets. Neither light, feeding space, ambient temperature nor RH had any effect on percentage abdominal fat.

10. Broilers given IL in both experiments had a lower incidence and less severe leg abnormalities than birds provided CL.

Based on the results from these two experiments, the following conclusions are presented:

1. Broilers provided IL have heavier body weights and similar feed efficiencies at market age than those reared on CL.

2. Broilers fed higher versus lower amino acid diets have improved gains and feed efficiencies at 49 days of age.

3. Increasing feeding space from 1.47 to 2.94 cm per bird improved body weight gain over the growth period.

4. Providing high ambient temperature (29 to 28^{o} C versus 29 to 22^{o} C) until four weeks of age improved feed efficiency while lower temperatures (28 to 26^{o} C versus 22 to 18^{o} C), thereafter, resulted in heavier broiler body weights.

5. Higher levels of relative humidity (70% versus 40%) during the brooding period resulted in heavier body weights at 28 days of age, with no effect noted when marketed.

6. Birds fed high versus low amino acid diets had more abdominal fat at market age.

7. Broilers provided IL had less severe and a lower incidence of leg abnormalities than birds given CL.

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THE EFFECT OF NUTRITION AND ENVIRONMENT

ON BROILER TYPE CHICKENS

by

Jeanna Louise Wilson

(ABSTRACT)

Influence of light, dietary amino acid levels, feeding space, and ambient temperature on male broiler body weight, feed efficiency, percentage abdominal fat, and incidence and severity of leg abnormalities was studied in two experiments.

Broilers subjected to intermittent light (1 hr on:2 hrs off) had heavier 49 day body weights, and similar feed efficiencies than birds given continuous illumination. Feeding high [106 and 114% of NRC for lysine and total sulfur amino acids (TSAA), respectively] versus low (100% of NRC for lysine and TSAA) amino acid diets, improved body weight and feed efficiency at market age. Providing broilers with increased feeding space (from 1.47 to 2.94 cm/bd) resulted in improved body weight at market age.

Birds under high ambient temperatures (29 to 26^{o} C) had significantly higher feed efficiencies at four weeks of age than those given low temperatures (29 to 18^{o} C). However, at market age broilers provided low temperatures had significantly greater gains with similar feed efficiencies.

Birds fed high amino acid diets had significantly more abdominal fat than those given low amino acid diets. Light, feeding space,

ambient temperature and relative humidity had no significant effect on percentage abdominal fat.

Broilers provided intermittent light had significantly fewer and less severe leg abnormalities than birds under continuous illumination. Dietary amino acids, ambient temperature and relative humidity had no significant effect on the incidence or severity of the leg disorders.